Importance of fragmentation functions in determining polarized parton densities [1]

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Abstract

New fragmentation functions (FFs) are extracted from a NLO QCD fit to the *preliminary* COMPASS data on pion and kaon multiplicities. It is shown that the new kaon FFs are very different from those of De Florian at al. (DSS) and Hirai et al. (HKNS). The sensitivity of the extracted polarized PDFs to the new FFs is discussed.

In the absence of charged current neutrino data, the experiments on polarized inclusive deep inelastic lepton-nucleon scattering (DIS) yield information only on the sum of quark and antiquark parton densities $\Delta q + \Delta\bar{q}$ and the polarized gluon density ΔG. In order to extract separately Δq and $\Delta\bar{q}$ other reactions are needed. One possibility is to use the *polarized* semi-inclusive lepton-nucleon processes (SIDIS) $l + N \to l' + h + X$, where h is a detected hadron (pion, kaon, etc) in the final state. In these processes new physical quantities appear - the fragmentation functions $D^h_{q,\bar{q}}(z, Q^2)$ which describe the fragmentation of quarks and anti-quarks into hadrons. Due to the different fragmentation of quarks and anti-quarks, the polarized parton densities Δq and $\Delta\bar{q}$ can be determined separately from a combined QCD analysis of the data on inclusive and semi-inclusive asymmetries. However, for their correct determination a good knowledge of the fragmentation functions is very important. It turned out that the use of the DSS set of FFs [1] leads to the so called strange quark polarization puzzle [2], *i.e.* the contradiction between the negative polarized strange quark density obtained from analyses of inclusive DIS data alone and the positive values for this density, for most of the range of measured x, obtained from combined analyses of inclusive and semi-inclusive SIDIS data. The significant difference in the kaon sector between the DSS FFs and the other sets of FFs [3] results from the use of the

[1] A talk given at the 20th International Symposium on Spin Physics (SPIN2012) JINR, Dubna, Russia, September 17 - 22, 2012.

unpublished HERMES'05 unpolarized SIDIS data on the hadron multiplicities, used only in the DSS analysis. However, the new preliminary HERMES data [4], as well as the COMPASS ones [5] are not in agreement with the DSS FFs and therefore, this set can not be favored at present. It is important to mention that the data on hadron multiplicities in the unpolarized SIDIS processes are crucial for a reliable determination of FFs, because only they can separate $D_q^h(z,Q^2)$ from $D_{\bar{q}}^h(z,Q^2)$.

In this talk we present our results on new fragmentation functions extracted from the *preliminary* COMPASS 2004 deuteron data on pion and kaon multiplicities [5] in NLO QCD approximation. We discuss also their impact on the determination of the polarized sea quark densities, and in particular, the status of the strange quark polarization puzzle.

The multiplicitiy $M_d^h(x,Q^2,z)$ of hadrons of type h ($h=\pi^+,\pi^-,K^+,K^-$) using a deuteron target is defined as the number of hadrons produced, normalized to the number of DIS events, and can be expressed in terms of the semi-inclusive cross section σ_d^h and the inclusive cross section σ_d^{DIS}:

$$M_d^h(x,Q^2,z)=\frac{d^3N^h(x,Q^2,z)/dxdQ^2dz}{d^2N^{DIS}(x,Q^2)/dxdQ^2}=\frac{d^3\sigma_d^h(x,Q^2,z)/dxdQ^2dz}{d^2\sigma_d^{DIS}(x,Q^2)/dxdQ^2}. \quad (1)$$

The data on the multiplicities are presented in different ways. In our fit we have used the $2D(x,z)$ presentation. In this presentation the values of the multiplicities are given for four z-bins [0.2-0.3; 0.3-0.45; 0.45-0.65; 0.65-0.85] as a function of different (x,Q^2) bins. Note that for a given z-bin and given (x_i,Q_i^2)-bin the multiplicity corresponds to the *average* number of hadrons detected.

We will discuss here mainly our results on the fit to the data on kaon multiplicities for two reasons: *i)* the big difference between the kaon FFs obtained by the different groups, and *ii)* the set of kaon FFs used in the combined analysis of the polarized inclusive and semi-inclusive DIS data is crucial for the determination of the polarized strange density. In the analysis 90 experimental points (45 for K^+ and 45 for K^-) have been taken. The errors used are quadratic combinations of the statistical error and half of the systematic error due to the kaon identification by the RICH detector. The number of free parameters, attached to the input parametrizations of the kaon FFs $[D_u^{K+}(z),\ D_{\bar{u}}^{K+}(z),\ D_{\bar{s}}^{K+}(z), D_g^{K+}(z)]$ at $Q^2=1\ GeV^2$ and determined from the fit, is 13. The assumption that all unfavored kaon FFs are equal is used. The charm contribution to the multiplicities is not taken into account. For the value of χ^2/DOF corresponding to the best fit to the data we obtain 137.8/77=1.79. A good description of the COMPASS kaon

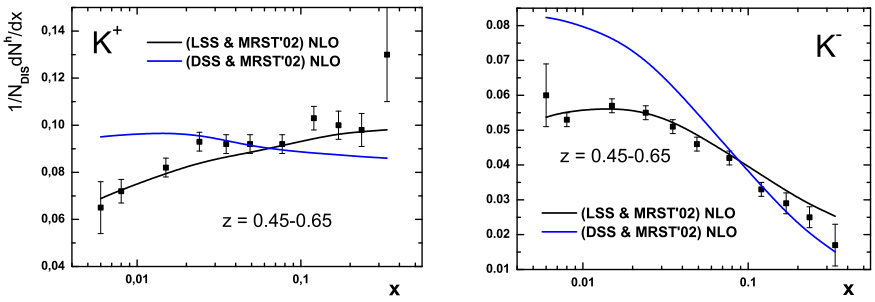

Figure 1: Comparison between COMPASS kaon data for z_3-bin and the best fit curves corresponding to the new FFs. The curves corresponding to DSS FFs are also presented. In both the cases the NLO MRST'02 set was used for the unpolarized PDFs.

data is achieved (for the quality of the fit see Fig. 1). The new NLO kaon FFs are presented in Fig. 2. As seen from Fig. 2 the new FFs are very different

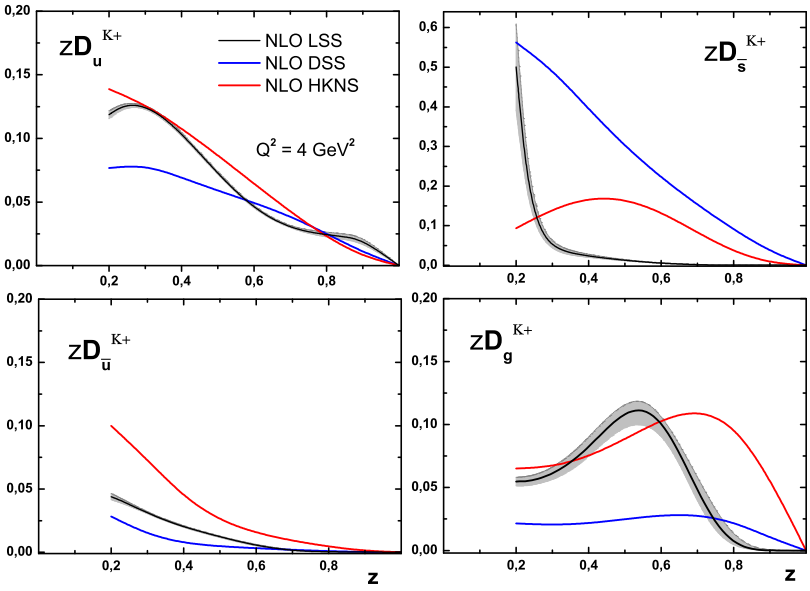

Figure 2: Comparison between NLO LSS, DSS and HKNS kaon FFs at $Q^2 = 4\ GeV^2$.

from those of DSS and HKNS (2nd ref. in [3]). This is especially the case

for the favored $D_{\bar{s}}^{K^+}(z, Q^2)$ which changes very rapidly between z=0.2 and z=0.3.

Using the new pion and kaon FFs we have performed a combined NLO QCD analysis of the world polarized inclusive and semi-inclusive DIS data in order to study their impact on the polarized parton densities. Compared to the values of the polarized sea quark densities obtained in our analysis [6] using the DSS FFs, the changes are as follows: negligible for $\Delta\bar{u}(x)$, visible for $\Delta\bar{d}(x)$, but still within the error band, and *significant* for $\Delta\bar{s}(x)$. As seen from Fig. 3, $x\Delta\bar{s}(x)$ is negative for any x in the measured region and *consistent* with that obtained from the pure DIS analysis [7]. The *final* COMPASS and HERMES data on the hadron multiplicities will be crucial in reliably determining the fragmentation functions and polarized PDFs, as well as for the resolution of the strange quark polarization puzzle.

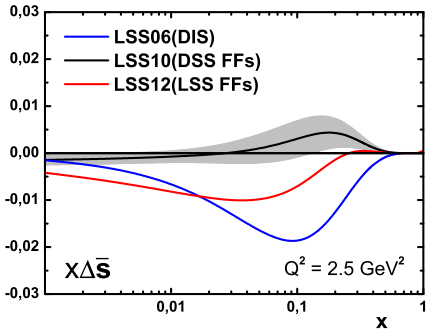

Figure 3: Comparison between polarized strange quark densities obtained from different kinds of NLO QCD analyses (see the text).

This research was supported by the JINR-Bulgaria Collaborative Grant and the RFBR Grants (Nrs 10-02-01259 and 11-01-00182).

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